THE GLACIERS

OF THE CANADIAN ROCKIES AND SELKIRKS.

MOUNT SIR DONALD AND GREAT GLACIER.

MOUNT ASSINIBOINE AND GLACIERS, NEAR BANFF, ALBERTA.

GLACIERS

FORMERLY it was thought that if one would enjoy really fine mountains he must travel to Switzerland, but now the Alps of that country have come to be the yardstick by which we measure the Rockies of our western world. The reason for this is obvious. Apart from their grandeur and beauty as masses of bare rock and verdure, the Rockies have the added attraction of their everlasting snow fields and mighty glaciers, making a combination of color and light effect which is not to be obtained except in regions of lofty mountains. It is largely for these attractions that the Canadian Rockies and Selkirks, which are now easily reached by the Canadian Pacific Railway, are becoming better known each year to tourists. Of these, those best qualified to judge, are unanimous in the opinion, that all things considered, this new Alpine region is greatly superior to that of the old world.

It is to answer some of the questions respecting the glaciers of this region that this publication has been prepared, in the hope of inspiring a greater love for Nature, and a greater interest in her works.

The first questions that naturally present themselves are *what are glaciers*, and how are they formed Broadly speaking, the definition is that a glacier is an accumulation of ice of sufficient size to flow down from a snow covered elevation. It is a river flowing from a lake, the latter up near the summit of a great range or peak, the former pouring down into the valley below, only, it is a lake of snow and a river of ice! The thickness of the ice will vary greatly according to local conditions, and when these are favorable

LONE TREE LAKE AND GLACIER IN PTARMIGAN VALLEY.

may be as much as 1,000 feet or more. Frequently glaciers extend far below the snow line of the region, because their great masses of ice are so thick that they are not entirely melted during the warm summer months.

Whilst glaciers exist in the United States, as far south as Central California, it is not until the northern international boundary is approached that they are found in any great size or numbers ; but after the traveller reaches the Rocky Mountains of Canada he finds them threading their way down from almost every high peak. Here the mountain chains are narrower than further south, aggregating a total width of less than five hundred miles. Where the railway traverses them there are four principal parallel ranges, the Coast Range, the Gold Range, the Selkirks and the Rockies. The last two are the highest and most rugged, and it is among their heights that the conditions for producing glaciers are seen to greatest advantage.

If a map of the Pacific Ocean on which the currents have been located is examined, it will be seen that the Japan current, after flowing past the Islands of Japan, divides into two unequal parts. The smaller of these takes a northeast direction through Behring Sea and Strait into the Arctic Ocean, while the larger portion assumes an eastern and then a southeastern course, bathing the west coast of British North America. The evaporation from this stream of warm water is very rapid, and the moist winds, the prevailing direction of which is toward the east, soon reach the coast line of North America and the ranges of mountains beyond. Nearly at right angles to the path of these moist winds lie the parallel ranges of the Rocky Mountains. The Cascade and Gold Ranges not being high, the clouds pass over them with a comparatively small precipitation on the western slopes, but on reaching the higher and more rugged ranges of the Selkirks and Rockies, cooling takes place more quickly and precipitation is very rapid. It is for this reason that on the western slopes of these mountains the snow is always deeper than on the eastern. The clouds as they rise to cross the individual ranges are cooled, and give up their moisture which is precipitated before the summits are reached.

These cold parallel ranges, bathed in warm winds laden with moisture

CAVE IN BALFOUR GLACIER.

which is constantly condensed upon the mountain tops, offer the most favorable conditions for the formation of glacier streams. The precipitation being heavy and the summer short, there is not time for all the snow which falls in a single year to melt and drain away in the form of water. An indefinite accumulation would now take place were it not that Nature has made another of her marvellous provisions to meet just this situation of affairs, for the snow forms into compact ice streams, or glaciers, which flow, just as rivers would, down the mountain sides to the valleys below. Here, under milder conditions of climate, the rate of melting is much more rapid, and keeps pace with the precipitation on the mountains above.

It thus becomes apparent that the primary function of a glacier and a river are identical, namely the drainage of a certain district or basin, only in one case the stream is solid and in the other liquid. It has been found that this resemblance applies in other particulars, and that almost every characteristic of a river has a parallel in the glacier. Exactly how and why a glacier moves has been studied for years, and has not yet been explained to the satisfaction of all, but the fact undoubtedly exists and may easily be proved by hundreds of observations. The stream at the centre of a glacier moves much faster than the sides or the bottom, while on a curve the outside edge has a more rapid rate of flow than the inside. At a narrow point the flow is more rapid than at a broad one, and in especially uneven places the ice may be broken up into pinnacles, just as water foams through a rapid. This phenomenon is well illustrated in the Yoho Glacier at the head of the Yoho Valley, near Field, British Columbia. The flow of a glacier is in large measure caused by the attraction of gravitation just as is the flow of a river. The movement of the ice is, of course, infinitely more slow than that of the water, and its action can perhaps be best imagined by considering the way in which thick mortar flows when poured out of a bucket. At all events it has been abundantly proved that even so firm and solid a substance as ice does flow under the conditions we have pictured.

We see then that the supply to the glacier is from moisture which is precipitated on the tops of high mountains during practically the entire

AN AVALANCHE ON MOUNT VICTORIA, NEAR LAKE LOUISE.

(The whole of the foreground is the Victoria Glacier, here buried beneath the rocks and stones carried down by avalanches from the cliffs above. The avalanche seen in picture, a little to the left of the centre, is falling about 1,800 feet.)

year. This falls mostly in the form of fine, sand-like, granular snow. Under the influence of the clear atmosphere a part of this snow evaporates directly into the air, to be reprecipitated on the ranges to the east. But by far the larger portion is compacted under the influence of cold and pressure till it reaches the state of clear, hard ice, like that which freezes on our rivers, except that owing to its peculiar formation the crystalline structure is different. The upper part of a glacier where this change from snow to ice is constantly going on is called the "névé region." In nearly all glaciers the snow of the névé is underlaid with a mass of ice which gradually approaches the surface as the melting of the snow above increases as the glacier descends. At a certain point this covering of snow disappears entirely, and beyond it, the clear, solid ice is seen at the surface. Below this is called the "dry glacier," but the position of this dividing line varies greatly from season to season and from month to month, as the depth of snow increases during a snowstorm or decreases during a long hot summer.

When subjected to pressure ice yields and will change its form readily, but under conditions of tension it is brittle and will crack and splinter. This property is one of the causes of the great cracks or crevasses which appear in nearly all glaciers. Owing to an uneven bed, change in course, or even the more rapid central flow, great crevasses will form. At times these may be hundreds of feet in length and fifty or sixty feet across.

The meltings from the glacier often flow on the surface for some distance till a crevasse is reached down which they leap to the rock bed below. In many instances beautiful waterfalls are seen. Sometimes deep wells or moulins are formed, filled with water, or at the bottom of which the sounds of running water may be heard. (See plates II. and III.)

When the bed of the glacier is steep the surface of the ice becomes very much broken, and where lateral and transverse crevasses intersect seracs are found. This is the technical name given to ice towers and pinnacles. These often attain a height of many feet, and are most beautiful, appearing in the sunlight as though made of exquisitely banded white and blue marble.

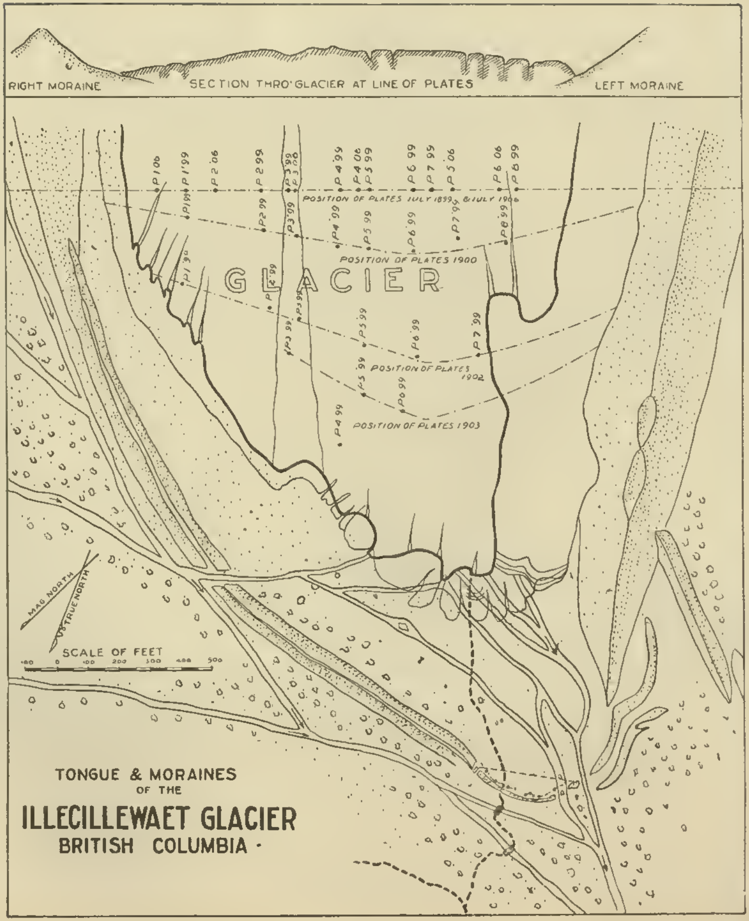
The power to transport rocks and other material over great distances

THE GREAT GLACIER, NEAR GLACIER HOUSE, B. C.

is one of the most interesting characteristics of glaciers. The rocks which fall on the névé from the cliffs above are soon buried under a bed of snow. This turns to ice as we have seen, and begins its slow but constant journey to the lower valleys, bearing its burden of rocks. A large part of the melting takes place at the surface of the ice where it is most exposed, so that stones once buried in the névé region gradually come to the surface as the ice above them melts. Here they ride along till deposited at the side or at the end of the glacier. In this way long regular heaps or moraines are formed, from which it is often easy to trace the many changes in the glaciers. (See Plate IV.) Moraines are designated by their position as respects the glacier. Individual glaciers vary greatly in the amount of material they thus carry down, owing to the proximity and condition of the cliffs above. The great avalanches which daily thunder down carry with them rocks of all sizes which are buried in the general mass. For some distance below the point where these avalanches fall the surface is clean and white, but below this point the rocks begin to appear and ride along on the surface to the great terminal moraine—a journey requiring many years, possibly centuries, to accomplish. (See Plate V.) A number of surface characteristics may be noted on this glacier. The small stones sink slightly into the ice because they absorb heat from the sun which melts the ice below. The larger ones are so thick that they do not become heated through in an entire day, and so protect the ice. The effect of this is that the stones rise on little pedestals of ice, which gradually become higher, till undermined by the heat entering from the sides the stones fall, only to begin the operation afresh. When piles of small stones collect together they form sand cones, owing to a similar protection to the body of ice below. Sometimes these assume peculiar shapes, and often it is hard to believe that the stones have not been piled up by human hands.

IN THE LAKE LOUISE REGION.

From the Chalet at Lake Louise, the Victoria Glacier is prominently visible. It rises on the great white summit of Mt. Victoria, and following


RIGHT MORAINE
SECTION THRO' GLACIER AT LINE OF PLATES
LEFT MORAINE
POSITION OF PLATES JULY 1899 & JULY 1906
POSITION OF PLATES 1900
GLACIER
POSITION OF PLATES 1902
POSITION OF PLATES 1903
MAG. NORTH
TRUE NORTH
SCALE OF FEET
TONGUE & MORAINES
OF THE
ILLECILLEWAET GLACIER
BRITISH COLUMBIA.

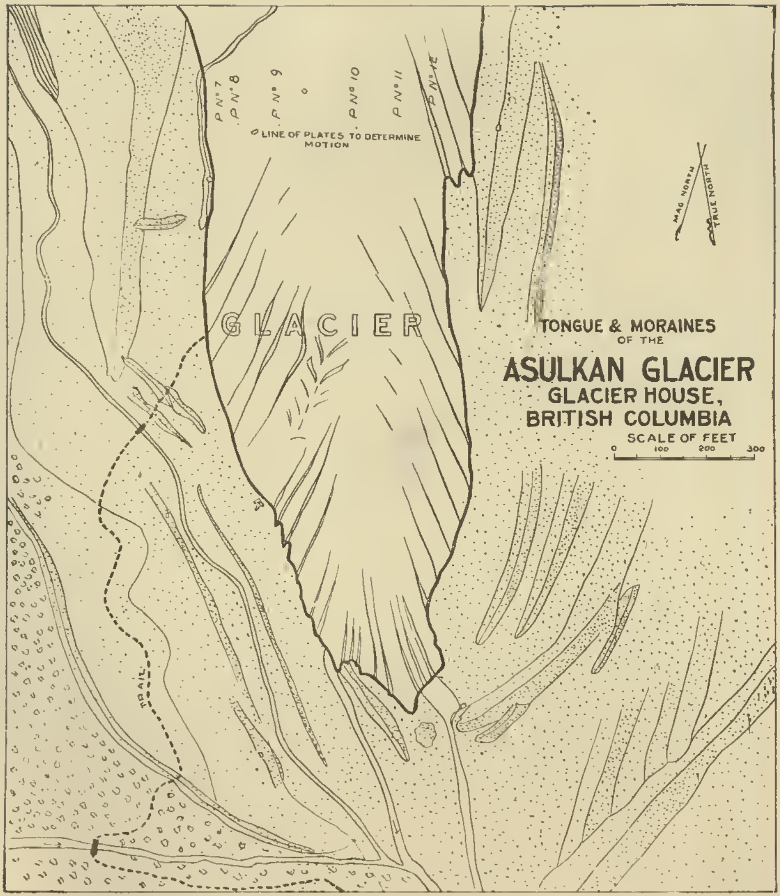
down the upper portions of the peak finally avalanches over the rock cliffs to the lower glacier. Confluents also flow in from Abbot Pass and from the large area lying at the foot of the mitre and from between Mts. Lefroy and Aberdeen. The lower Victoria Glacier is easily reached from the Chalet. The visitor should follow the trail along the shore of the Lake, or take one of the row boats to its head. A continuation of the trail leads over the shingly flats composed of old moraine, and from it the ice is easily reached, within about two miles of the hotel. In some places there is a high, steeply-sloping ice wall, which cannot be scaled without steep cutting. At other points, however, the surface of the ice may be reached easily. All of the lower portions are flat and free from crevices. However in higher atmospheres there are crevices sometimes spanned by treacherous snow bridges, where the novice should not venture except under the direction of a competent guide. On a summer afternoon a succession of fine avalanches may frequently be seen, sometimes as many as thirty or forty in an hour. They are most interesting to watch as they come pouring down over the stupendous precipices. Whilst their thunder is not infrequently heard at the Chalet, the point where most of them fall cannot be seen from that end of the Lake.

The surface phenomena as noted above can be studied to unusual advantage on the Victoria Glacier.

Paradise Valley lying to the east of that in which Lake Louise lies has at its head the Horseshoe Glacier. It is distant from the Chalet some ten miles, and can be reached by a good trail in a couple of hours. The surroundings are very imposing, with Mt. Hungabee looming up at the head of the valley. This glacier is also deeply buried in morainal material. A very beautiful and remarkable sinuous canon worn in the ice, will well repay a visit.

No visitor to Lake Louise, who can spare a day or longer, will fail to visit Moraine Lake, and the Valley of the Ten Peaks, the next valley further east than Paradise Valley.

The distance is about eleven miles from the Chalet over an excellent trail. About two miles further up the Valley and at its head, lies the great



P. Nº 7
P. Nº 8
P. Nº 9
P. Nº 10
P. Nº 11
P. Nº 12
LINE OF PLATES TO DETERMINE MOTION
MAG NORTH
TRUE NORTH
GLACIER
TONGUE & MORAINES
OF THE
ASULKAN GLACIER
GLACIER HOUSE,
BRITISH COLUMBIA
SCALE OF FEET
0
100
200
300
TRAIL

Wenkchemna Glacier which in recent times seems to have proved an exception to the almost universal rule that glaciers are retreating. The cause of the retreat is that melting takes place more rapidly than is provided for by the supply of snow and ice coming down from above.

The recent annual reports of the "Commission Internationale des Glaciers" show that during the latter half of the nineteenth century the greater number of the observed glaciers in all parts of the world have been receding, and those of the Rockies and Selkirks are no exception. We have examined a great many glaciers in the regions adjacent to the railroad, and the results of our own observations, as well as those of others, have been almost without exception, that the glaciers are universally retreating. There are a few exceptions to this, however, and fortunately some of these are now easily accessible. The Asulkan Glacier, near Glacier House, advanced a few years ago, though we have no definite measurement of the precise amount. Recently, however, it has receded again. The most notable example, however, is the great glacier of the Ten Peaks, extending down almost to Moraine Lake, which has been steadily advancing, and it is most interesting to observe how the heavy frost is being destroyed by its resistless force. (See Plate VI.) Probably local causes are responsible. The glacier is hemmed in on the eastward by a continuation of stupendous cliffs. At some date, not very remote, an unusual avalanche of rocks, of enormous proportions, has buried the ice deep in piles of huge stones and boulders, which, preventing the access of the sun's rays, protect it from much melting. There seems no good reason why this state of affairs should not continue to exist for many years, perhaps centuries, as the conditions are likely to recur.

FIELD.

The glacier on the side of Mt. Stephen, high above the railroad as the train descends the Kicking Horse Pass to Field, is a source of much interest to and comment by tourists. At places it appears to overhang the track and at times great pieces of ice which break off from it roll down the mountain side.

THE SULZER GLACIER, SELKIRKS, B. C.

The principal glaciers that are visited from Field are those of the Yoho Valley. The Yoho glacier at the head of this valley, which is the source of the Yoho River, will well repay a visit. It is almost too long a trip, however, for one day. This glacier usually ends in a very beautiful ice arch from which the stream gushes with great violence. The frequent falling of masses of ice from the ceiling of the arch makes caution necessary in approaching closely. Beginning with July 1906, the Alpine Club of Canada has conducted a series of observations on this glacier with the object of measuring its rate of flow.

GLACIER HOUSE.

The glacier which is undoubtedly most frequently visited of any in British Columbia, is the Great or Illecillewaet Glacier, familiar to everyone who has been so fortunate to be a guest at Glacier House. Since the summer of 1887 it has been observed with more or less care. At that time it covered the great bed moraine of boulders which now extends from the edge of the ice to the fringe of alder bushes. A number of rocks can be identified upon which, in different years, the position of the ice has been marked with paint

During the summers of 1899, 1900, 1902, 1903, 1906, 1907, 1909 and 1910, accurate measurements were taken for determining the exact rate of flow of this glacier, for of course glaciers vary according to the local conditions of steepness and curvature of their beds, supplies of ice from the névés, etc.

In July, 1899, a station was selected far up on the right moraine, and here a surveyor's transit was set up. A number of steel plates, painted red for ease of identification, were laid out on the ice in a straight line across the glacier. This line was about fifteen hundred feet above the forefoot of the ice. Of course as the glacier moved the plates were carried down with it. In July, 1900, in 1902, and again in August, 1903, with the transit the amount of this motion from the original position in which the plates had been put was measured. The first year showed a daily advance near the center of between six and seven inches, which decreased towards the edges. More

MT. SIR DONALD AND GREAT GLACIER, FROM MT. ABBOTT.

recently, however, the average rate of flow appears to be slowly diminishing, being in some places nearly a quarter of an inch less per day, At the point of measurement the width of the glacier was about one-third of a mile.

During the summer of 1906 another set of plates was laid out on this glacier from which similar measurements were deduced and again this operation was repeated in the summers of 1909 and 1910.

Such variations in the rate of flow, help to account for another movement of the glacier, that of recession or advance up and down the valley through which it flows. As already remarked, in 1887, the Illecillewaet Glacier extended down to the edge of the alder bushes. Just to the left of the trail as it emerges from the scrub a large rock will be observed which fifteen years ago was firmly embedded in the glacier, the vertical paint line upon it having been carefully located from a photograph taken at that time, and shows where the edge of the ice then was. After 1887 for a year or two the changes were probably not very material. But from August, 1890, when a certain rock near the alder bushes was marked, till August 1898, the total amount of this retreat up the valley had been four hundred and fifty two feet, or an average of fifty-six feet per year.

During the succeeding five years ending in 1903 the average recession per year was about thirty-five feet. Then a marked change occurred, for till August 1904 the recession was reduced to about five feet and for 1905 the amount was only about two and one-half feet. Since then the recession has varied from year to year, that for the year ending in August 1910 having again increased to about sixty feet. The future of this glacier tongue will be observed with much interest. Predictions as to its future action seem quite impossible.

ASULKAN GLACIER.

Lying at the head of the valley of the same name, the Asulkan Glacier is also favorably located for the visitor, and possibly no valley in the immediate vicinity is more beautiful than this one. The glacier itself has a very fine ice fall. Its upper reaches are buried deep in snow, and are easily

reached under the direction of one of the Swiss guides. As noted above, this Glacier is also retreating in recent years with considerable rapidity. Measurements made upon its rate of flow indicate that it is moving less rapidly than the Illecillewaet.

We have sketched thus briefly some of the leading characteristics of glaciers in the hope that interest may be aroused in the subject of glacial action, and that visitors to the district reached by the Canadian Pacific Railway may have their attention called to it. There are many problems still to be solved, and it is only by careful and accurate observations covering a series of years that the facts can be learned by which theories may be crystallized into Nature's laws.

We have purposely avoided the domain of what is controversial, preferring to call attention to what may be observed rather than to the deductions which may be drawn from the observations.

A large portion of the scientific observations embodied in the foregoing pages, as well as the statements made, were the work of our brother, William S. Vaux, who, prior to his death in 1908, had devoted a great deal of time to the subject. We have carried on the later investigations with the able assistance of Mr. A. O. Wheeler, A.C.C.

Bryn Mawr, Penna.
May 1911.

Mary M. Vaux.
George Vaux, Jr.

GLOSSARY.

Bergschrund.—The great crevasse separating the commencement of a snow field from the mountain side.

Crevasse.—A crack extending into the ice, often of great width and depth.

Dry Glacier—The lower part of the glacier where it is free from snow..

Glacier-Table.—A large block of stone on a dry glacier, balanced on a column of ice.

Moraines.—The piles of rocks and stones surrounding a glacier and which have been transported by it.

Moulin.—A shaft or well cut through a glacier by a stream.

Névé.—The snow field from which a glacier flows.

Serac.—An ice tower formed by the intersection of transverse and longitudinal crevasses.

Tongue or Snout.—The end of the glacier ; the fore-foot.